

SCH 3U – Grade 11 Academic Chemistry

UNIT & TITLE OF LESSON: Quantities in Chemical Reactions – <u>The Limiting Reactant</u>	
<p><u>BIG IDEAS:</u></p> <ul style="list-style-type: none"> - Relationships in chemical reactions can be described quantitatively. - The efficiency of chemical reactions can be determined and optimized by applying an understanding of quantitative relationships in such reactions. 	<p>MATERIALS</p> <ul style="list-style-type: none"> <input type="checkbox"/> Graham crackers, marshmallows, chocolate <p>APPENDICES</p> <ul style="list-style-type: none"> <input type="checkbox"/> Appendix A.1: <i>What's Limiting You? Student instructions</i> <input type="checkbox"/> Appendix A.2: <i>What's Limiting You? Teacher's notes</i> <input type="checkbox"/> Appendix B.1: Student worksheet on limiting reactant: <i>The Limiting Reactant</i> <input type="checkbox"/> Appendix B.2: Teacher's notes on the limiting reactant <input type="checkbox"/> Appendix C.1: Homework question <input type="checkbox"/> Appendix C.2: Homework answer <input type="checkbox"/> Appendix D: Ticket out of class
<p><u>OVERARCHING QUESTION:</u> How are Avogadro's number, the mole, and molar mass related and why is it important that health care professionals ensure accountable calculations of prescription dosages?</p>	
<p><u>MOE SPECIFIC EXPECTATIONS:</u></p> <p><u>A1.1.</u> Formulate relevant scientific questions about observed relationships</p> <p><u>D1.1.</u> Analyse processes in the home, the workplace, and the environmental sector that use chemical quantities and calculations, and assess the importance of quantitative accuracy in industrial chemical processes;</p> <p><u>D2.1</u> use appropriate terminology related to quantities in chemical reactions, including, but not limited to: stoichiometry, percentage yield, limiting reagent, mole, and atomic mass.</p> <p><u>D2.3.</u> Solve problems related to quantities in chemical reactions by performing calculations involving quantities in moles, number of particles, and atomic mass</p> <p><u>D2.5</u> calculate the corresponding mass, or quantity in moles or molecules, for any given reactant or product in a balanced chemical equation as well as for any other reactant or product in the chemical reaction.</p> <p><u>D2.6</u> solve problems related to quantities in chemical reactions by performing calculations involving percentage yield and limiting reagents</p> <p><u>D3.2.</u> Describe the relationships between Avogadro's number, the mole concept, and the molar mass of any given substance.</p>	
<p><u>PRIOR KNOWLEDGE:</u></p> <ul style="list-style-type: none"> - Understanding of moles and molar ratios - Comfortable with writing and balancing chemical equations - Knowledge of mole conversions 	
<p><u>LEARNING GOALS:</u></p> <ul style="list-style-type: none"> - Students will have a clear understanding of what a limiting reagent is - Students will understand that the amount of product produced is strongly dependent on the limiting reagent - If given a problem, students will be able to write a balanced chemical equation; determine the limiting reagent and determine the amount of product that will be formed - Students will be able to make a connection between limiting reagents and its application to real life scenarios 	
<p><u>ASSESSMENT AND EVALUATION:</u></p> <p><i>Knowledge and Understanding:</i></p> <ul style="list-style-type: none"> - Demonstrate understanding of a limiting reagent; calculations of limiting reagents; mole conversions - Identifying the limiting reagent in a sample problem <p><i>Thinking/Inquiry:</i></p> <ul style="list-style-type: none"> - Identifying relationship between limiting reagent and the amount of product able to be produced <p><i>Communication:</i></p>	

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| <ul style="list-style-type: none">- Using appropriate SI unit to work through a problem- Communicating the answers from the calculations to the class through step-by-step explanations | |
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Application:

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| <ul style="list-style-type: none">- Linking the concept of limiting reagents to real-life examples- Connecting the calculations learnt to a medical example | |
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TIMING	TEACHING/LEARNING STRATEGY	RESOURCES/NOTES	RATIONALE
Before: Minds On (12min)	<p>1. Smores Activity to Introduce Limiting Reactants</p> <p>In groups of 4, have students build as many smores as they can with ingredients provided. One smore consists of 2 crackers, 1 marshmallow, and 2 chocolate pieces. Students answer questions on handout.</p>	<p>Graham crackers, marshmallows, chocolate, <i>What's Limiting You?</i> handout</p> <p>See Appendices A</p>	<p>Everyone loves food (approach to target different learning styles)</p> <p>AFL – ensure students understand the concept of a limiting ingredient</p>
During: Action (45 min)	<p>3. Connecting Smores Activity to Limiting Reactant (20 min)</p> <p>Transition from using smores to chemical equations. Distribute <i>Limiting Reactant Worksheet</i> handout and demonstrate one or two examples on the board, involving students in each step.</p> <p>4. Pair/Share Activity to Complete Worksheet (25 min)</p> <p>In pairs, students complete remainder of questions on worksheet. Teacher guides students as needed.</p>	<p><i>Limiting Reactant Worksheet</i> handout</p> <p>Blackboard notes</p> <p>See Appendices B</p>	<p>Students use existing knowledge of mole conversions to determine limiting reactant and predict amount of product.</p> <p>AFL – ensure students can apply prior knowledge to new concept.</p> <p>AAL – providing descriptive feedback to partner, responding to teacher descriptive feedback</p>
Consolidate (18 min)	<p>1. Students take up one question on blackboard (10 min)</p> <p>Teacher asks students to write the answer to one question on the blackboard. Students should describe each step to the class as they go.</p> <p>2. Antacid as an Example of a Real Life Limiting Reactant (5 min)</p> <p>Teacher explains the purpose and composition of an Alka-Seltzer. Students will determine which ingredient in an Alka-Seltzer is the limiting reactant.</p> <p>3. Ticket out of class (3 min)</p>	<p>Homework question</p> <p>See Appendices C</p> <p>See Appendix D</p>	<p>AAL – students explaining to class; AOL – students demonstrate to teacher their understanding of concept of limiting reactant and how it is used to calculate amount of product</p> <p>STSE connection keeps students engaged and makes science relevant in life.</p> <p>AAL –students reflection on the day's lesson</p>

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Appendix A.1: Student Handout: *What's Limiting You?*

Name:

What's Limiting You?

Scenario:

We are surrounded around a campfire, have our sticks and are all set to start roasting some marshmallows to make Smores. A Smore consists of graham crackers, marshmallows and chocolate. The exact components of one Smore is:

- one marshmallow
- two pieces of chocolate
- two graham crackers



Instructions:

1. Arrange yourself into groups of 4.
2. At the centre of the table, gather all the materials to make smores.
3. Using **ONLY** the materials provided on the table, make as many smores as you can.
Remember that 1 smore = 2 crackers + 2 chocolates + 1 marshmallow
4. When you can no longer make any smores, count how many you were able to make using the materials that were provided to you.

Questions:

1. How many smores were you able to make?
2. What limited you from making more smores?
3. What ingredients were in excess?

What's Limiting You?

Materials:

- class of 28 students
- 7 groups of 4
- each group gets:
 - o 4 marshmallows (need 4 to make 4 smores)
 - o 10 chocolates (would need 8 to make 4 smores)
 - o 12 crackers (would need 8 to make 4 smores)
- each group will make 4 smores because there is not enough to make 5 or 6

Scenario:

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- one marshmallow
- two pieces of chocolate
- two graham crackers



Instructions:

5. Arrange yourself into groups of 4.
6. At the centre of the table, gather all the materials to make smores.
7. Using **ONLY** the materials provided on the table, make as many smores as you can.
Remember that 1 smore = 2 crackers + 2 chocolates + 1 marshmallow
8. When you can no longer make any smores, count how many you were able to make using the materials that were provided to you.

Questions:

4. How many smores were you able to make?
4
5. What limited you from making more smores?
Marshmallows
6. What ingredients were in excess?
Chocolate and crackers

Name:

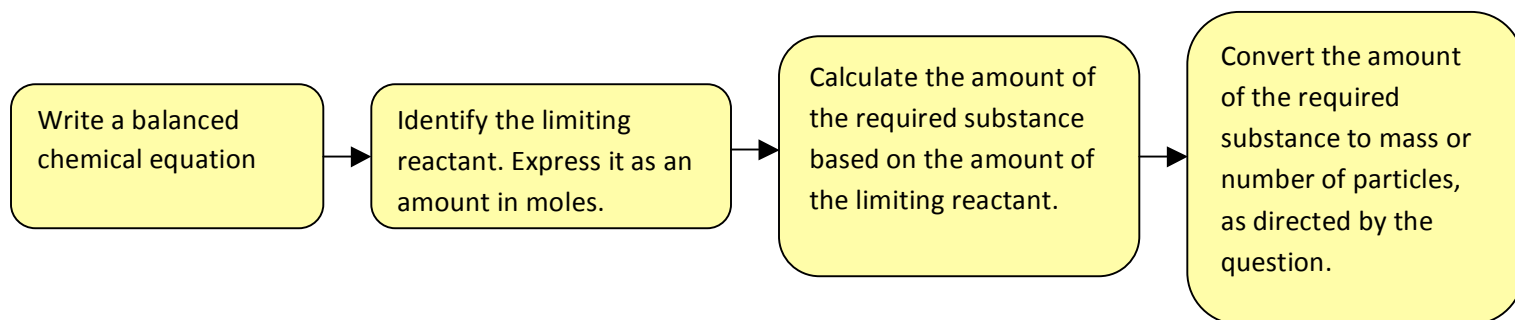
The Limiting Reactant

The limiting reactant

What is the relationship between a limiting reactant and a product in a chemical reaction?

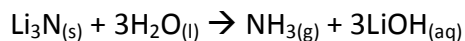
Excess reactant

In partners, use your knowledge of mole conversions and mass relationships to answer the following questions. You can follow the steps below to solve stoichiometric calculations.



Questions

1) Lithium nitride reacts with water to form ammonia and lithium hydroxide, according to the following balanced chemical equation:

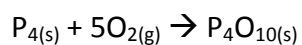


If 4.87 g of lithium nitride reacts with 5.80 g of water, find the limiting reactant.

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2) 3.76 g of zinc reacts with 8.93×10^{23} molecules of hydrogen chloride. Which reactant is present in excess?

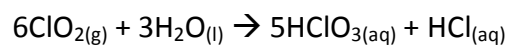
3) White phosphorus consists of a molecule made up of four phosphorus atoms. It burns in pure oxygen to produce tetraphosphorus decaoxide.



A 1.00 g piece of phosphorus is burned in a flask filled with 2.60×10^{23} molecules of oxygen gas. What mass of tetraphosphorus decaoxide is produced?

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4) Chloride dioxide, ClO_2 is a reactive oxidizing agent. It is used to purify water.



a) If 71.00 g of ClO_2 is mixed with 19.00 g of water, what is the limiting reactant?

b) What mass of HClO_3 is expected in part (a)?

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Appendix B.2 Teacher's notes: *The Limiting Reactant*

Name:

The Limiting Reactant

In the smores activity, the limiting reactant was the marshmallow. In most chemical reactions, there is also a limiting reactant.

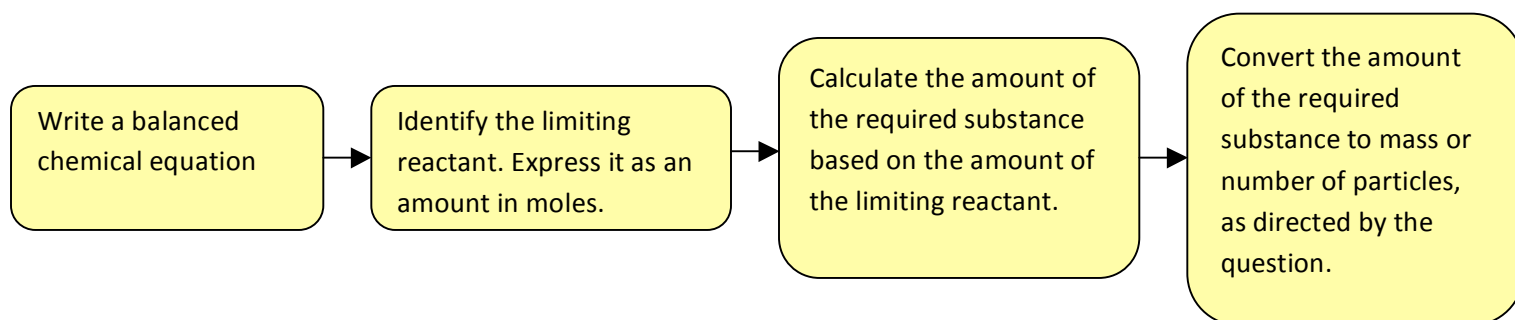
The **limiting reactant** is the reactant that is completely used up in a chemical reaction. When the limiting reactant is used up, the reaction stops.

Question: From the smores activity, what is the relationship between the limiting reactant and a product in a chemical reaction?

Expected answer: The amount of product formed depends on the amount of limiting reactant available.

Similar to the smores activity where you had an excess of crackers and chocolate left over... A reactant that remains after a reaction is over is called the **excess reactant**.

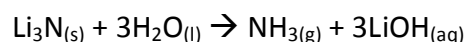
In partners, use your knowledge of mole conversions and mass relationships to answer the following questions. You can follow the steps below to solve stoichiometric calculations.



Questions

Guide students through each step using above process, but also asking them to recall which equations to use.

1) Lithium nitride reacts with water to form ammonia and lithium hydroxide, according to the following balanced chemical equation:



If 4.87 g of lithium nitride reacts with 5.80 g of water, find the limiting reactant.

- convert mass to moles for Li_3N

$$\begin{aligned} n \text{ mol Li}_3\text{N} &= \frac{4.87 \text{ g Li}_3\text{N}}{34.83 \text{ g/mol}} \\ &= 0.140 \text{ mol Li}_3\text{N} \end{aligned}$$

- pick any product to calculate (NH_3 – since 1 mole is produced) based on amount of Li_3N

$$\begin{aligned} n \text{ mol NH}_3 &= \frac{1 \text{ mol NH}_3}{1 \text{ mol Li}_3\text{N}} (0.140 \text{ mol Li}_3\text{N}) \\ &= 0.140 \text{ mol NH}_3 \end{aligned}$$

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- convert mass to moles for H₂O

$$\begin{aligned}n \text{ mol H}_2\text{O} &= \frac{5.80 \text{ g H}_2\text{O}}{18.015 \text{ g/mol}} \\&= 0.322 \text{ mol H}_2\text{O}\end{aligned}$$

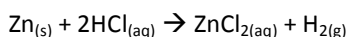
- calculate amount of NH₃ made, based on amount of H₂O

$$\begin{aligned}n \text{ mol} &= \frac{1 \text{ mol NH}_3}{3 \text{ mol H}_2\text{O}} (0.322 \text{ mol H}_2\text{O}) \\&= 0.107 \text{ mol NH}_3\end{aligned}$$

Therefore, the limiting reactant is water because the water produces less NH₃ compared with Li₃N. Notice there is more water than lithium nitride, in terms of mass and moles. But because 3 mol of water are needed to react with 1 mol of lithium nitride, water is the limiting reactant.

2) 3.76 g of zinc reacts with 8.93×10^{23} molecules of hydrogen chloride. Which reactant is present in excess?

- write a balanced chemical equation



-convert mass to moles for Zn

$$\begin{aligned}n \text{ mol Zn} &= \frac{3.76 \text{ g Zn}}{65.409 \text{ g/mol}} \\&= 0.057 \text{ mol Zn}\end{aligned}$$

- calculate amount of H₂ made, based on amount of Zn

$$\begin{aligned}n \text{ mol H}_2 &= \frac{1 \text{ mol H}_2}{1 \text{ mol Zn}} (0.057 \text{ mol Zn}) \\&= 0.057 \text{ mol H}_2\end{aligned}$$

- convert molecules to moles

$$\begin{aligned}n \text{ mol HCl} &= \frac{8.93 \times 10^{23} \text{ molecules}}{6.02 \times 10^{23} \text{ molecules/mol}} \\&= 1.483 \text{ mol HCl}\end{aligned}$$

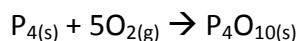
- calculate amount of H₂ made, based on amount of HCl

$$\begin{aligned}n \text{ mol H}_2 &= \frac{1 \text{ mol H}_2}{2 \text{ mol HCl}} (1.483 \text{ mol HCl}) \\&= 0.742 \text{ mol H}_2\end{aligned}$$

Therefore, Zn is the limiting reactant because it produces less H₂ compared with HCl. Zn is completely used up in the reaction, so HCl is thus the excess reactant that remains after the reaction stops.

Students to complete last 2 questions with partner.

3) White phosphorus consists of a molecule made up of four phosphorus atoms. It burns in pure oxygen to produce tetraphosphorus decaoxide.



A 1.00 g piece of phosphorus is burned in a flask filled with 2.60×10^{23} molecules of oxygen gas. What mass of tetraphosphorus decaoxide is produced?

- convert mass to moles for P₄

$$\begin{aligned}n \text{ mol P}_4 &= \frac{1.00 \text{ g P}_4}{123.893 \text{ g/mol}} \\&= 0.00807 \text{ mol P}_4\end{aligned}$$

- calculate amount of P₄O₁₀ is made, based on amount of P₄

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$$\begin{aligned}n \text{ mol P}_4\text{O}_{10} &= \frac{1 \text{ mol P}_4\text{O}_{10}}{1 \text{ mol P}_4} (0.00807 \text{ mol P}_4) \\&= 0.00807 \text{ mol P}_4\text{O}_{10}\end{aligned}$$

- convert molecules to moles for O₂

$$\begin{aligned}n \text{ mol O}_2 &= \frac{2.60 \times 10^{23} \text{ molecules O}_2}{6.02 \times 10^{23} \text{ molecules/mol}} \\&= 0.432 \text{ mol O}_2\end{aligned}$$

- calculate amount of P₄O₁₀ made, based on amount of O₂

$$\begin{aligned}n \text{ mol P}_4\text{O}_{10} &= \frac{1 \text{ mol P}_4\text{O}_{10}}{5 \text{ mol O}_2} (0.432 \text{ mol O}_2) \\&= 0.0864 \text{ mol P}_4\text{O}_{10}\end{aligned}$$

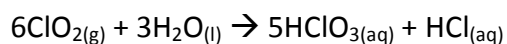
Therefore, the limiting reactant is P₄.

- convert mass to moles for P₄O₁₀, using amount calculated from P₄

$$\begin{aligned}g \text{ P}_4\text{O}_{10} &= 0.00807 \text{ mol P}_4\text{O}_{10} \times 283.886 \text{ g/mol} \\&= 2.29 \text{ g P}_4\text{O}_{10}\end{aligned}$$

Therefore, the amount of P₄O₁₀ is 2.29 g.

4) Chloride dioxide, ClO₂ is a reactive oxidizing agent. It is used to purify water.



a) If 71.00 g of ClO₂ is mixed with 19.00 g of water, what is the limiting reactant?

- convert mass to moles for ClO₂

$$\begin{aligned}n \text{ mol ClO}_2 &= \frac{71.00 \text{ g ClO}_2}{67.451 \text{ g/mol}} \\&= 1.053 \text{ mol ClO}_2\end{aligned}$$

- calculate amount of HClO₃ formed, based on amount of ClO₂

$$\begin{aligned}n \text{ mol HClO}_3 &= \frac{5 \text{ mol HClO}_3}{6 \text{ mol ClO}_2} (1.053 \text{ mol ClO}_2) \\&= 0.8775 \text{ mol HClO}_3\end{aligned}$$

-convert mass to moles for H₂O

$$\begin{aligned}n \text{ mol H}_2\text{O} &= \frac{19.00 \text{ g H}_2\text{O}}{18.015 \text{ g/mol}} \\&= 1.055 \text{ mol H}_2\text{O}\end{aligned}$$

- calculate amount of HClO₃ formed, based on amount of H₂O

$$\begin{aligned}n \text{ mol HClO}_3 &= \frac{5 \text{ mol HClO}_3}{3 \text{ mol H}_2\text{O}} (1.055 \text{ mol H}_2\text{O}) \\&= 1.758 \text{ mol HClO}_3\end{aligned}$$

Therefore, the limiting reactant is ClO₂ because it produces less amount of HClO₃ compared with H₂O.

b) What mass of HClO₃ is expected in part (a)?

- convert moles of HClO₃, made by the limiting reactant ClO₂, to mass

$$\begin{aligned}g \text{ HClO}_3 &= 0.8775 \text{ mol HClO}_3 \times 84.458 \text{ g/mol} \\&= 74.1 \text{ g HClO}_3\end{aligned}$$

Therefore, the mass of HClO₃ produced is 74.1 g.

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Appendix C.1 Student worksheet

Name:

Limiting Reactants in Everyday Life

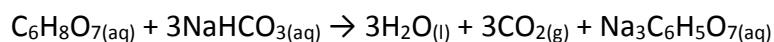
Have you ever experienced the effects of excess stomach acid (or acid indigestion)?

Did you take an antacid, such as Alka-Seltzer, for relief?

Alka-Seltzer functions by **neutralizing** excess stomach acid. The fizz you observe when the tablets are placed in water is due to carbonation (dissolving carbon dioxide in water).



The main ingredients in an Alka-Seltzer tablet are **citric acid** and **sodium bicarbonate**. These two ingredients react when placed in water, and form the following chemical equation:



In an experiment, 1.00 g of citric acid and 1.92 g of sodium bicarbonate are allowed to react.

- Which ingredient is the limiting reactant?
- How many grams of carbon dioxide form?
- How many grams of excess reactant remain after the limiting reactant is completely consumed?
- What is the purpose/function of this excess reactant? (think neutralization reaction)

Limiting Reactants in Everyday Life

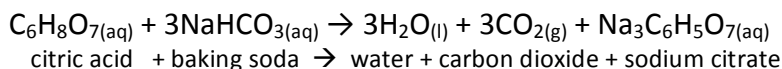
Have you ever experienced the effects of excess stomach acid (or acid indigestion)?

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Alka-Seltzer functions by **neutralizing** excess stomach acid. The fizz you observe when the tablets are placed in water is due to carbonation (dissolving carbon dioxide in water).



The main ingredients in an Alka-Seltzer tablet are **citric acid** and **sodium bicarbonate**. These two ingredients react when placed in water, and form the following chemical equation:



In an experiment, 1.00 g of citric acid and 1.92 g of sodium bicarbonate are allowed to react.

a) Which ingredient is the limiting reactant?

- convert mass to moles for citric acid

$$\begin{aligned} n \text{ mol C}_6\text{H}_8\text{O}_7 &= \frac{1.00 \text{ g C}_6\text{H}_8\text{O}_7}{192.123 \text{ g/mol}} \\ &= 5.20 \times 10^{-3} \text{ mol C}_6\text{H}_8\text{O}_7 \end{aligned}$$

- calculate amount of H₂O formed, based on amount of C₆H₈O₇

$$\begin{aligned} n \text{ mol H}_2\text{O} &= \frac{3 \text{ mol H}_2\text{O}}{1 \text{ mol C}_6\text{H}_8\text{O}_7} (5.20 \times 10^{-3} \text{ mol C}_6\text{H}_8\text{O}_7) \\ &= 0.0156 \text{ mol H}_2\text{O} \end{aligned}$$

- convert mass to moles for baking soda

$$\begin{aligned} n \text{ mol NaHCO}_3 &= \frac{1.92 \text{ g NaHCO}_3}{84.015 \text{ g/mol}} \\ &= 0.0229 \text{ mol NaHCO}_3 \end{aligned}$$

- calculate amount of H₂O formed, based on amount of NaHCO₃

$$\begin{aligned} n \text{ mol H}_2\text{O} &= \frac{3 \text{ mol H}_2\text{O}}{3 \text{ mol NaHCO}_3} (0.0229 \text{ mol NaHCO}_3) \\ &= 0.0229 \text{ mol H}_2\text{O} \end{aligned}$$

Therefore, the limiting reactant is the citric acid.

b) How many grams of carbon dioxide form?

- calculate amount of CO₂ formed, based on amount of citric acid

$$\begin{aligned} n \text{ mol CO}_2 &= \frac{3 \text{ mol CO}_2}{1 \text{ mol C}_6\text{H}_8\text{O}_7} (5.20 \times 10^{-3} \text{ mol C}_6\text{H}_8\text{O}_7) \\ &= 0.0156 \text{ mol CO}_2 \end{aligned}$$

- convert moles to mass

$$\begin{aligned} \text{g CO}_2 &= 0.0156 \text{ mol CO}_2 \times 44.009 \text{ g/mol CO}_2 \\ &= 0.687 \text{ g CO}_2 \end{aligned}$$

Therefore, 0.687 g of carbon dioxide is formed.

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c) How many grams of excess reactant remain after the limiting reactant is completely consumed?

- find how much sodium bicarbonate is consumed in reaction by using the moles of the limiting reactant

$$n \text{ mol NaHCO}_3 = \frac{3 \text{ mol NaHCO}_3}{1 \text{ mol C}_6\text{H}_8\text{O}_7} (5.20 \times 10^{-3} \text{ mol C}_6\text{H}_8\text{O}_7)$$

$$= 0.0156 \text{ mol NaHCO}_3$$

Therefore, 0.0156 mol of NaHCO₃ is consumed during the reaction with citric acid.

- convert moles to grams

$$g \text{ NaHCO}_3 = 0.0156 \text{ mol NaHCO}_3 \times 84.015 \text{ g/mol}$$

$$= 1.31 \text{ g NaHCO}_3$$

Therefore, 1.31 g of NaHCO₃ is consumed during the reaction.

- to find how much remains, subtract initial amount by the consumed amount

$$g \text{ NaHCO}_3 = 1.92 \text{ g} - 1.31 \text{ g}$$

$$= 0.61 \text{ g NaHCO}_3$$

Therefore, 0.61 g of NaHCO₃ remains after the reaction is complete.

d) What is the purpose/function of this excess reactant? (think neutralization reaction)

Sodium bicarbonate helps to decrease acidity in the stomach (HCl) in a neutralization reaction to neutralize excess stomach acids, producing water and carbon dioxide.

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Appendix D: *Ticket out of class*

Exit Ticket: Rate how comfortable you feel solving problems involving limiting reagents.

Rating Scale:

1	2	3	4	5
Not very comfortable				Very comfortable